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THE CFB SUMMERSIDE PROJECT
INITIAL OPERATING EXPERIENCE WITH 18 TPH AFBC HEATING BOILERS

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JUNE 1983

For presentation at the International Workshop on the Design and Operation of Atmospheric Pressure Fluidized Bed Boiler/Combustor, Technical University of Nova Scotia, Halifax, Nova Scotia, June 23 and 24, 1983.

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
DIVISION REPORT 83-40 (TR)

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by

V. V. Razbin* and F. D. Friedrich**

ABSTRACT

Initial operating experience with Canada's first commercial FBC boiler plant, located at CFB Summerside, PEI, is described. The plant, consisting of two boilers rated at 18,000 kg/h of steam at MCR, operating at 965 kPa saturated steam, is designed for high-sulphur coal with supplementary firing of wood chips. The boilers were operated intermittently from December 1982 until May 1983, and in May one boiler was subjected to an acceptance test campaign of about two weeks, during which it performed satisfactorily, at loads ranging from 110% MCR to the maximum design turndown ratio of 4.5:1. Assessment of its performance in terms of efficiency and emissions awaits completion of laboratory analyses and data reduction.

Careful control of limestone sizing is required to avoid the problems with cold fluidization which were encountered during commissioning. Also, high moisture and fines in the coal caused significant problems in the materials handling system. Some erosion of boiler tubes in the bed zone was observed. The affected areas were covered with a thin layer of hard refractory to prevent further deterioration. This does not appear to have a detrimental effect on steam output.

Further work remains to be done, but it appears likely that during the next heating season both boilers will be fully commissioned and all requirements for acceptance will be met.

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LE PROJET DE LA BFC SUMMERSIDE
UNE PREMIÈRE EXPLOITATION DE CHAUDIÈRES DE CHAUFFAGE À COMBUSTION EN LIT FLUIDISÉ SOUS PRESSION ATMOSPHÉRIQUE D'UNE CAPACITÉ DE 18 TONNES PAR HEURE

par V.V. Razbin* et F.D. Friedrich**

RÉSUMÉ

Il s'agit d'une expérience initiale d'exploitation de la première installation canadienne à échelle commerciale de chaudières à combustion en lit fluidisé, menée à la Base des Forces canadiennes Summerside dans l'Île-du-Prince-Édouard. L'installation, comportant deux chaudières d'une capacité nominale de 18 000 kg/h de vapeur en régime continu maximal (MCR) fonctionnant à 965 kPa de vapeur saturée, est étudiée pour brûler du charbon à teneur élevée en soufre et des copeaux de bois comme combustible supplémentaire. On a exploité les chaudières de façon intermittente entre décembre 1982 et mai 1983; une chaudière a subi en mai une campagne d'homologation de deux semaines environ, pendant laquelle elle a fonctionné de façon satisfaisante à des charges dont la gamme allait de 110 % du régime continu maximal (MCR) jusqu'au rapport maximal de 4,5:1 de débit moyen nominal. Il faut attendre les résultats des analyses en laboratoire et la réduction des données avant de procéder à l'évaluation des caractéristiques de fonctionnement en termes d'efficacité et d'émissions.

Il importe de surveiller de près la granulométrie du calcaire afin d'éviter les problèmes associés à la fluidisation à froid constatés lors de la mise en service. En outre, l'humidité élevée et les fines du charbon ont entraîné des problèmes importants pour les organes de manutention; on a constaté un certain degré d'érosion des tubes des chaudières dans la zone du lit. Les zones touchées ont été recouvertes d'une mince couche de réfractaire endurci pour éviter qu'elles se détériorent davantage; la production de vapeur ne semble pas en avoir été touchée.

Il faut poursuivre les travaux, mais il semblerait qu'au cours de la prochaine saison de chauffage on pourra mettre les deux chaudières en service à plein temps et satisfaire à toutes les exigences d'homologation.

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INTRODUCTION

Fluidized-bed combustion (FBC) is perceived world-wide as an emerging technology for utilizing high-sulphur fuels while providing adequate control of acid rain precursors, notably SO and NO_x. In Canada this aspect of FBC technology is augumented by its potential for dealing with low-grade fuels having combinations of high moisture, high ash, and low combustion reactivity. Energy, Mines and Resources Canada has accordingly developed, over the past ten years, a substantial program of research, development and demonstration, focused mainly on atmospheric FBC The main objective of this program is to expede the application of this technology in both industrial steam-raising and utility power generation.

A major component of the EMR program is the CFB Summerside project; the first commercial demonstration of FBC boilers in Canada. This demonstration is being carried out in collaboration with Defence Canada and consists of a two-boiler heating plant which will ultimately provide the main steam supply for the military base at Summerside, PEI. The history of the project dates back to 1977, and by the end of 1982, a complete new heating plant containing two FBC boilers each rated at 18,000 kg/h of steam, was in place. Commissioning and acceptance testing were initially scheduled to be completed by the end of February 1983. Although encouraging progress has been made and each boiler has been operated for several hundred hours, circumstances which will be described later have made it necessary to defer most of the acceptance tests until the 1983-84 heating season. The authors therefore regret that at present they can offer only preliminary data, obtained on one boiler during a test program in mid-May 1983.

PLANT LAYOUT AND DESIGN

The construction phase of the project was preceded by three years of studies in which two competing teams of designers, each led by a boiler manufacturer, prepared first conceptual, then detailed designs and firm

proposals for the proposed heating plant. The terms of reference, the two designs, and the procedure by which the contractor for the construction phase was selected, have already been described[1].

START-UP AND OPERATING EXPERIENCE

Materials Handling System

The coal, stored in an outdoor stockpile, is reclaimed by a front-end loader and then delivered to the heating plant in dump trucks. Despite substantial precautions taken in design, the in-plant coal handling system encountered frequent and fairly severe problems caused by the combination of high moisture and high fines content in the coal, which was occasionally aggravated by contamination with earth from the stockpile area. Numerous interruptions to boiler operation were caused by fine coal particles sticking to the chute between the vibrating screen and the first bucket elevator, by fines sticking to and blinding the elevator buckets, by erratic discharge of coal from the storage bunkers, and by coal sticking to the flights of various screw conveyors. At times continuous monitoring and physical intervention was required to keep the coal moving through the system. Relocating the low level alarm on the coal daybin provided the operators with an adequate margin of time to cope with blockages in the system upstream. These problems are neither new nor related to fluidized bed combustion per se; the mechanical handling of fine, wet coal has always been problematic, and considering the winter climate of Prince Edward Island, the outdoor stockpile is likely to cause a persistent problem. The system performed well with dry coal; difficulties began when the surface moisture exceeded about 8%, depending on fines content.

The limestone is delivered on demand, by covered truck, direct from the preparation plant at Havelock, New Brunswick to the heating plant. On one occasion when 6 mm x 0 limestone was being delivered, the vibrating screen became clogged with wet, fine particles. Whenever double-screened limestone (8 mesh x 20 mesh) was delivered, the handling system performed satisfactorily.

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[1] Taylor, M.E.D. and Friedrich, F.D. "The CFB Summerside project; Canadian state-of-the-art in AFBC boilers"; Division Report ERP/ERL 82-10; Energy Research Laoratories; CANMET; Energy, Mines and Resources Canada; 1982.

Boiler Operation

Early in December 1982 Havelock limestone sized at 6 mm x 0 was introduced into Bed A of Boiler No. 1 to test fluidization under cold conditions. This first attempt to fluidize a limestone bed was successful, but air leaks from the windbox were detected. After these were sealed all attempts to fluidize the same limestone failed, with or without operation of the oil-fired overbed light-up burner. It was necessary to remove the 6 mm x 0 limestone from the bunker, and replace it with limestone double-screened to 8 mesh x 20 mesh (2.4 mm x 0.8 mm) in order to achieve fluidization.

In the subsequent five months of intermittent operation it was found that limestone top size and size distribution were critical for cold fluidization and hence boiler start-up. The optimum limestone sizing for the present distributor plate design has not yet been determined, but it has been demonstrated that if the limestone contains more than 10% of +8 mesh material, cold fluidization is generally not possible. Difficulties encountered by the limestone supplier in providing adequate control of sizing contributed significantly to delays in commissioning.

It may be easier to light the boilers with spent bed material than with fresh limestone, since test work to date has shown that spent bed material has a bulk density of 1335 kg/m^3, whereas the fresh limestone has a bulk density of 1400 kg/m^3 to 1500 kg/m^3.

During the first few days of operation, hot bed material began to leak through the seal between the distributor plates and the furnace water walls. This problem was resolved by welding light-gauge stainless steel angle sections to the water walls and the distributor plates. A similar technique was successful in the FBC boiler at Georgetown University.

Twice during the course of the winter, Boiler No. 1 experienced massive clinkering of the beds. In both cases the root causes were high bed temperature combined with reducing conditions, although lack of experience in FBC boiler operation was a contributing factor. On the first occasion, a power failure caused the beds to slump at a time when the coal hoppers contained fine, dry coal from a nearly empty bunker. When power was restored and the induced draft fan was brought back into operation, the high furnace draft sucked this coal into the furnace even

though the stockers were not operating. The resulting oversupply of coal, burning in a pile on the bed, produced massive clinkers when the the forced draft fan was restarted a few minutes later. On the second occasion a test to explore lower limits for excess air was in progress and the bed had been allowed to build up to an excessive depth causing elutriating material to jam one of the spreader stokers. When coal feed failure was noted on the boiler alarm panel, the forced draft fan was unwisely tripped, resulting in clinker.

In March 1983 inspection of the boiler tube surfaces exposed to the fluidized beds in Boiler No. 1 revealed polishing and wall thickness reduction on all walls at a height of about 600 mm above the distributor plate. The pattern of polishing at the tube welds indicated that erosion was caused by a downflow of bed material at the furnace walls. To prevent further deterioration the boiler manufacturer installed a belt of refractory about 25 mm thick, around the inside of each bed, beginning at 550 mm above the distributor plate, and extending upward 600 mm. The refractory has a high thermal conductivity, and subsequent operation has indicated that it does not seriously impair heat transfer to the furnace tubes. The durability of the refractory remains to be seen. The in-bed tubes have not been similarly protected, since longer periods of operation are required to establish whether they are subject to erosion.

Problems of limestone sizing, distributor plate sealing and refractory installation have delayed commissioning and acceptance testing by several months. However, each boiler has been operated for over 500 h, and No. 2 boiler was operated continuously for 2-1/2 weeks from its first light-up, before being shut down to install protective refractory on the furnace tubes. It was subsequently put back in service for a two-week program of calibration and efficiency tests and another week to burn out the remaining coal on the bunkers before being shut down for the summer.

Baghouse and Bed Material Handling Systems

The baghouses for both boilers have performed very well to date. Each has a flue gas bypass duct which is used during each start-up and baghouse warm up. During each start-up and shut-down of the boilers the manufacturer's recommended procedures for baghouse operation were strictly followed.

The pulse-jet bag cleaning system and controls have performed well, maintaining a maximum pressure drop across the baghouse of a 140 mm water column. Under normal operating conditions, the stacks are clear.

The pneumatic ash handling system has performed well in transporting all baghouse ash, bed material, and on a few occasions, limestone that had to be removed from the storage bins to the ash storage silo. Operational problems were limited to replacement of one diaphragm on a pneumatic actuator. The ash handling system controls have also functioned well in both manual and automatic modes.

Fly Ash Reinjection Systems

Each boiler has two fly ash reinjection systems; one draining the mechanical dust collector, the other draining the boiler bank hopper. The fly ash trapped by the mechanical collector is reinjected into Bed A through a Perma-lock double lock hopper system. These have required excessive maintenance due to wear of the isolating valve components. Both valve shafts and bushings on each boiler have been replaced.

Fly ash from the boiler bank hopper is also reinjected into Bed A, through a pneumatic eductor system. The transport lines and reinjection nozzles eroded severely causing several shut-downs of the boilers. A permanent solution is still to be found.

On both the boiler bank and mechanical collector reinjection systems, blowback of bed material during boiler start-up caused the lines to plug. To prevent this the fly ash reinjection systems are operated routinely during start-up. Incidental benefits are that the hoppers are kept clear of fly ash accumulations, and additional air for cold fluidization is provided.

The reinjection blowers appear to be oversized; to reduce the amount of reinjection air the speed of the blowers has been reduced and some air has been bled to the outside of the building. The optimum quantity of reinjection air has yet to be established, and the problem of noise from the blowers has yet to be addressed.

PRELIMINARY RESULTS OF EFFICIENCY TESTS

According to contract requirements each FBC boiler shall meet the following conditions:

At Maximum Capacity Rating (MCR) and 65% MCR

- Boiler efficiency shall be at least 80% as measured by the ASME Short Form Test, indirect method;
- allowable emission levels shall not be exceeded;
- stack temperature shall not exceed 175°C.

At 110 MCR

- the boiler shall produce 19,800 kg/h of steam without exceeding the allowable emission levels.

At minimum load

- a steam output not exceeding 4000 kg/h (turndown ratio of 4.5:1) shall be maintained without operational difficulties;
- allowable emission levels shall not be exceeded.

At all loads

- the boilers shall be operated on automatic control except for the control function required to fix output.
- allowable emission levels are:

for SO_2: 2.96 kg/10^6 kcal heat input
(1.64 lb/10^6 Btu heat input)

for particulates: 0.36 kg/10^6 kcal heat input
(0.20 lb/10^6 Btu heat input)

By mid-May Boiler No. 2 was ready for acceptance tests against the foregoing requirements, except that calibration of the control system was not complete to permit operation under automatic control. Tests were conducted with the boiler under manual control, according to the following schedule:

65% MCR:	12 h
110% MCR:	4 h
MCR:	24 h
Minimum Load:	12 h

EMR/CANMET installed data logging equipment which recorded, every fifteen minutes, the output from all boiler control instrumentation during the tests. Simultaneously the boiler manufacturer's staff manually recorded, every thirty minutes, more than 100 instrument readings from the control panel and other boiler instrumentation.

The Centre for Energy Studies (CES) of the Technical University of Nova Scotia, contracted to measure stack emissions including particulates during the tests, used their instrument van on the site. Particulates were sampled, using the EPS 1-AP-74-1 method, through 100 mm ports installed in the stacks below the boilerhouse roof. The ports werereadily accessible from a specially designed platform. Iso-kinetic sampling and stack traversing were accomplished fairly conveniently, but difficulties with the particulate sampling system resulted in only one complete test for each load condition. Flue gas extracted from the stack through the particulates sampling probe was split into two streams. One passed through a set of bubblers for wet-chemistry determination of SO_2, the other was transferred via a heated pump and heated line to the analyzers in the instrument van. This provided continuous monitoring of CO_2, CO, O_2, SO_2 and NO_x. O_2 was also monitored by a plant analyzer which draws a gas sample from the duct between the mechanical collector and the economizer.

In addition to monitoring flue gas analysis and particulates, CES performed ultimate analyses on coal samples which were taken hourly during each test. EMR/CANMET and the boiler manufacturer took additional samples the analyses of which will be used to determine boiler efficiency.

Elaborate methods were employed to obtain reliable measurements of bed residue and baghouse ash flow rates, as well as representative samples for subsequent analyses of carbon content. This information is also required to calculate boiler efficiency.

At the time of writing, sample analyses and data reduction are not sufficiently advanced to establish boiler efficiency or emission levels. Preliminary results of coal analyses performed by CES are given in Table 1, and boiler operating data taken from the EMR datalogger and averaged for the 65% MCR and 100% MCR tests, are given in Table 2. Corresponding data on gaseous emissions, measured by CES, are given in Table 3. It should be noted that the O_2 concentration measured by the CES paramagnetic analyzer is on dry basis whereas that measured by the plant zirconium oxide analyzer, as given in Table 2, is on a wet basis.

While it is not possible to state whether boiler met the efficiency and emissions requirements, its capability to meet the steam output requirement and the stack temperature requirement has been clearly demonstrated. Furthermore the boiler operated well and without interruption throughout the two week test period. Load change on manual control was accomplished smoothly, and the standard deviations reported in Tables 2 and 3 attest to the steadiness of operation.

THE FBC DEMONSTRATION PROGRAM

The primary function of the FBC boilers at CFB Summerside is to provide heat for the base. They also provide an excellent opportunity to explore the capability of FBC technology in terms of different fuels and sorbents, which, with the collaboration of Defence Canada, will be fully utilized. EMR/CANMET is committed to a three-year program in which several eastern Canadian coals and limestones or dolomites will be tested. Moreover, co-firing of wood chips, which the boilers have been designed to accept, will be investigated to establish both technical and economic feasibility. The overall reliability of FBC boilers, as well as the economics of operation, particularly with respect to electric power consumption, will also be determined.

In collaboration with Environment Canada, environmental concerns relating to disposal of bed residue and fly ash will be addressed. Potential uses of residues as construction materials, and perhaps agricultural soil conditioners, will also be investigated.

The planned demonstration program at CFB Summerside will be a very significant step forward in reliable scale-up of FBC technology to industrial and utility applications.

CONCLUSIONS

Canada's first two commercial-scale FBC boilers were started up in December 1982, and each has since logged several hundred hours of operation. Some operational difficulties were encountered; the coal handling system does not perform reliably with coal containing a high fines content and surface moisture exceeding 8%, and the limestone size consist must be controlled to less than 10% weight on an 8-mesh screen to ensure cold fluidization on start-up. Tube erosion in the bed zone was observed, and protective refractory was installed to prevent further deterioration. Erosion and wear of fly ash reinjection system components appear to be excessive; suitable corrective measures have yet to be implemented.

Nonetheless, during a two-week test program conducted in May, 1983, one boiler readily met all capacity requirements and the full-load stack temperature requirements. Assessment of its performance in terms of efficiency and emissions awaits completion of laboratory analytical work and data reduction. In spite of the innovative nature of the technology, progress has been made, and it is expected that by the end of the 1983/84 heating season, the boilers will have demonstrated their ability to burn high-sulphur coal in a reliable, environmentally-acceptable manner.

Table 1 - Preliminary results; ultimate analysis of Devco Prince coal

		65% and 110% MCR Tests		MCR Tests		Design Coal
		As Received	Dry	As Received	Dry	Dry
Carbon	%	58.88	64.43	58.93	64.67	64.20
Hydrogen	%	3.70	4.05	3.70	4.06	4.00
Oxygen	%	16.00	18.28	15.60	17.94	6.00
Nitrogen	%	1.10	1.21	1.08	1.19	1.00
Sulphur	%	3.76	4.11	3.80	4.13	5.50
Moisture	%	8.60	-	8.87	-	
Ash	%	7.92	7.92	8.01	8.01	19.30
		99.96	100.00	99.99	100.00	100.00
Calorific Value	Btu/lb		11,590		11,640	11,500
Calorific Value	MJ/kg		26.9		27.0	26.7

Table 2 - Averaged boiler performance data from tests on Boiler No. 2, conducted May 12-15, 1983

		65% MCR		100% MCR	
		Mean Value	S. D.	Mean Value	S. D.
Steam Flow	kg/h	12500.0	419.5	18610.0	422.9
Drum Pressure	kPa	849.7	43.2	884.6	29.1
Stack Temperature	°C	134.6	2.9	166.0	1.3
FD Fan Discharge	mmH_2O	2019.0	4.5	2018.1	10.6
Bed "A" Plenum Pressure	mmH_2O	1155.2	69.2	1697.2	17.6
Bed "B" Plenum Pressure	mmH_2O	1066.0	44.0	1693.4	21.5
Bed "A" Total p	mmH_2O	735.3	19.2	729.0	21.2
Bed "B" Total p	mmH_2O	735.7	[illegible]8	718.7	17.2
Total Coal Feed	kg/h	1530.0	103.3	2023.0	159.6
Bed "A" Limestone Feed	kg/h	380.0	82.4	498.0	60.9
Bed "B" Limestone Feed	kg/h	470.0	40.2	513.0	47.5
Bed "A" Average Bed Temp	°C	879.0	9.0	885.5	18.8
Bed "A" Average Freeboard Temp	°C	455.6	12.8	518.1	12.1
Bed "B" Average Bed Temp	°C	871.2	9.9	878.2	14.2
Bed "B" Average Freeboard Temp	°C	443.8	9.3	560.6	10.1
Oxygen	%	5.8	0.6	6.4	0.5
Sulphur Dioxide	ppm	233.8	118.0	184.3	98.2

Table 3 - Averaged flue gas analyses from tests on Boiler No. 2, conducted May 12-15, 1983

		65% MCR				100% MCR			
		Max	Min	Mean	S.D.	Max	Min	Mean	S.D.
Carbon Dioxide	%	13.75	10.67	12.12	0.64	13.39	10.89	11.91	0.59
Carbon Monoxide	%	0.30	0.15	0.22	0.04	0.17	0.07	0.11	0.03
Oxygen	%	8.75	6.51	7.99	0.45	9.13	7.17	8.19	0.44
Sulphur Dioxide	ppm	508.00	26.00	158.00	108.60	598.00	67.00	169.00	99.00
NO_x	ppm	N/A				282.00	191.00	244.00	18.80